GEAR PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a gear pump used to send fluid under pressure.

Conventionally, a gear pump as disclosed, for example, in Japanese Laid-Open Patent Publication No. 2001-140770 has been known. This gear pump has a pump section 101 as shown in FIG. 9. The pump section 101 has two stages of gear trains 111, and each of the gear trains 111 has two pairs of drive gears 111a and driven gears 111b meshing with each other. In the pump section 101, a plurality of pump chambers 111c for conveying fluid are defined by the gears 111a and 111b. Both drive gears 111a are connected to a drive shaft 102 so as to be rotatable integrally with the drive shaft 102, and both driven gears 111b are supported by a driven shaft 103.

When the drive shaft 102 is rotated, both drive gears 111a connected to the shaft 102 rotate. When the drive gear 111a rotate, the corresponding driven gear 111b supported by the driven shaft 103, which meshes with the drive gear 111a, rotates following the rotation of the drive gear 111a. Therefore, the pump chambers 111c convey the fluid, and thereby the pressure of the fluid is increased.

In the above-described gear pump, each end portion of the drive shaft 102 and driven shaft 103 is supported via a bearing 104. For the reason of this support construction, a gap, i.e., an internal space 105 exists around the cylindrical surface of each of the shafts 102 and 103 at a position adjacent to the gears 111a and 111b in the pump section 101. Therefore, there arises a problem in that the fluid leaks from the pump chambers 111c into the internal space 105, so that

the efficiency of gear pump decreases.

There exists a fuel supply system for supplying a liquefied gas fuel such as dimethyl ether (hereinafter abbreviated to DME) to a vehicular internal combustion engine. This fuel supply system sometimes uses the above-described gear pump. The gear pump has no expansion stroke. Therefore, the gear pump is superior in handling DME that is easy to vaporize.

DME has a low viscosity and hence is liable to leak. Therefore, leakage of fluid, i.e., leakage of DME from the above-described pump chambers 111c into the internal space 105 poses a serious problem. The gear pump mounted on a vehicle is especially required to have a small size. Therefore, it is difficult to arrange a sealing member in a leakage path between the pump chambers 111c and the internal space 105.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a gear pump in which fluid leakage from pump chambers to an internal space is reduced.

To achieve the above-mentioned objective, the present invention provides a gear pump for sending fluid under pressure. The gear pump includes a pump section that draws fluid and discharges pressurized fluid. The pump section includes a gear train, a drive shaft and a driven shaft. The gear train has a pair of meshed gears. Each gear defines a plurality of pump chambers for conveying fluid in the pump section. The drive shaft has a cylindrical surface. One of the gears is coupled to the drive shaft such that the gear rotates integrally with the drive shaft. The driven shaft has a cylindrical surface. The driven shaft supports the other

one of the gears. The pump section has an internal space that is located at a position adjacent to at least one of the gears and about the cylindrical surface of at least one of the drive shaft and the driven shaft. The pressure atmosphere of the internal space is an intermediate pressure atmosphere of the pressure of fluid drawn into the pump section and the pressure of fluid discharged from the pump section.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a pump in accordance with a first embodiment of the present invention;

FIG. 1A is an enlarged view of a portion surrounded by a chain line 1A in FIG. 1;

FIG. 2 is a sectional view taken along the line II-II of FIG. 1;

FIG. 3 is a sectional view taken along the line III-III of FIG. 1;

FIG. 4 is a schematic view of a fuel supply system provided with the pump shown in FIG. 1;

FIG. 5 is an enlarged cross-sectional view of an essential portion of a pump in accordance with a second embodiment of the present invention;

FIG. 6 is a cross-sectional view of a pump in accordance with a third embodiment of the present invention;

FIG. 7 is a cross-sectional view of a pump in accordance with a fourth embodiment of the present invention;

FIG. 8 is a cross-sectional view of a pump in accordance with a fifth embodiment of the present invention; and

FIG. 9 is a cross-sectional view of a prior art pump.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First to fifth embodiments of the present invention will now be described. In the second to fifth embodiments, only points different from the first embodiment are explained, that is, the same reference numerals are applied to the same or equivalent elements, and the explanation thereof is omitted.

As shown in FIG. 4, a fuel supply system has a two-stage gear pump 1. The fuel supply system supplies a fuel to an internal combustion engine (an engine), which is a driving source for running a vehicle. The suction side of the pump 1 is connected to a tank 2 through a suction pipe 3. The tank 2 stores DME (dimethyl ether) used as fluid, or as a liquefied gas fuel. The discharge side of the pump 1 is connected to an injection pump 5 through a discharge pipe 4. An engine 6 is connected to the discharge side of the injection pump 5. The injection pump 5 supplies the DME, which is sent under pressure from the pump 1, to the engine 6 in a high-pressure state.

As shown in FIG. 1, the pump 1 has a casing 7 and a lid 9. The lid 9 is fixed to the opening end of the substantially bottomed cylindrical casing 7, that is, at the left end as viewed in FIG. 1 via a plurality of bolts 8. The casing 7 and the lid 9 constitute a pump housing of the pump 1. The pump 1 is mounted on the vehicle in a state such that the left-hand side as viewed in FIG. 1 is the upper side and the right-hand side therein is the lower side. The casing 7 contains a motor

section 10 fixed to the internal surface of the lid 9 and a pump section 11 connected to the motor section 10. Thus, the pump 1 incorporates a motor 10. That is to say, the pump 1 requires no external drive source, and the interior of the pump 1 is sealed from the outside. In the casing 7, a space outside the motor section 10 and the pump section 11 forms a sub tank 7a. In the motor section 10 and the pump section 11, a drive shaft 12 is rotatably provided through these portions.

The motor section 10 has a substantially bottomed cylindrical motor housing 10a. The motor section 10 includes stators 10b and a rotor 10c. Each stator 10b has a winding arranged along the inner circumferential surface of the motor housing 10a. The rotor 10c consists of an iron core arranged in a state of being surrounded by the stators 10b. In the motor section 10, that is, in the motor housing 10a, a space containing the stators 10b and the rotor 10c constitutes a motor chamber 60. The rotor 10c is fixed to and rotates integrally with the drive shaft 12. The winding of each stator 10b is connected to a terminal 15. When a current is caused to flow in the winding of the stators 10b via the terminals 15 by the power supplied from the outside, the drive shaft 12 is rotated by electromagnetic induction between the winding and the iron core of the rotor 10c.

As shown in FIGS. 1 and 1A, the pump section 11 includes a base block 16, a connection plate 19, a side plate 20, a connection plate 21, and a tip-end plate 22 in that order from the motor section 10. The base block 16 and the plates 19 to 22 are fixed to each other by a plurality of through bolts 23 (see FIGS. 2 and 3) in a state in which the drive shaft 12 is inserted. The pump section 11 is fixed to the motor section 10 by fixing a flange portion 16a of the base block 16 to the motor housing 10a via a plurality of bolts 24 (in FIG. 1, only one bolt is shown).

The drive shaft 12 extends through the base block 16 and the plates 19 to 22. The upper end (left end in FIG. 1) of the drive shaft 12 is supported by the motor housing 10a via a bearing 13. On the end surface of the motor housing 10a, a recess 61 that opens toward the lid 9 is formed. The upper end of the drive shaft 12 and the bearing 13 are located in the recess 61. The lower end (right end in FIG. 1) of the drive shaft 12 is supported by the tip-end plate 22 via a bearing 14. The tip-end plate 22 is formed with a recess 62. The lower end of the drive shaft 12 and the bearing 14 are located in the recess 62. The bearings 13 and 14 each consist of a needle bearing serving as a roller bearing.

As shown in FIG. 1A, a groove 12a is formed in part of the outer circumferential surface that is in the vicinity of the lower end the drive shaft 12. The groove 12a extends in the axial direction of the drive shaft 12. In the groove 12a, a key 25 having a substantially rectangular shape in cross section is arranged.

As shown in FIGS. 1 to 3, on the drive shaft 12, a first drive gear 26 and a second drive gear 27 are provided in that order from the lower end along the axial direction of the drive shaft 12. On the outer circumferential surfaces of the drive gears 26 and 27, teeth 26a and 27a are formed, respectively. In the inner circumferential surfaces of the drive gears 26 and 27, key grooves 26b and 27b are formed, respectively. The drive gears 26 and 27 each are made to be rotatable integrally with the drive shaft 12 by engaging the key 25 with the surface defining the key groove 26b, 27b.

In the pump section 11, a driven shaft 29 is rotatably housed in parallel with the drive shaft 12. The driven shaft 29 extends through the base block 16 constituting the pump

section 11 and the plates 19 to 22 constituting the pump section 11. The upper end (left end as viewed in FIG. 1) of the driven shaft 29 is supported by the base block 16 via a bearing 30. The base block 16 is formed with a recess 63. The upper end of the driven shaft 29 and the bearing 30 are located in the recess 63. The lower end (right end in FIG. 1) of the driven shaft 29 is supported by the tip-end plate 22 via a bearing 31. The tip-end plate 22 is formed with a recess 64. The lower end of the driven shaft 29 and the bearing 31 are located in the recess 64. The bearings 30 and 31 each consist of a needle bearing serving as a roller bearing.

On the driven shaft 29, a first driven gear 32 and a second driven gear 33 are provided in that order from the lower end side along the axial direction of the driven shaft 29. On the outer circumferential surfaces of the driven gears 32 and 33, teeth 32a and 33a are formed, respectively. The first driven gear 32 is provided so as to be rotatable relatively to the driven shaft 29. The second driven gear 33 is formed integrally with the driven shaft 29. The first driven gear 32 meshes with the corresponding first drive gear 26 on the drive shaft 12, and the second driven gear 33 meshes with the corresponding second drive gear 27 on the drive shaft 12.

On the outer circumferential surface of the casing 7, a suction connecting portion 35 is provided. The suction connecting portion 35 has a suction port 35a communicating with the sub tank 7a, and is connected with the suction pipe 3 extending from the tank 2 (see FIG. 4). The DME in the tank 2 is introduced through the suction pipe 3 and the suction port 35a, and is stored in the sub tank 7a. When the pump section 11 is operated, the pump section 11 sucks the DME in the sub tank 7a. The pump section 11 increases the pressure of DME

through a plurality of gear trains. That is, the pump section 11 is of a tandem type.

Specifically, the pump section 11 has a first-stage gear train 36 that is a first gear train, or a low-pressure side gear train, consisting of the first drive gear 26 and the first driven gear 32, and a second-stage gear train 37 that is a second gear train consisting of the second drive gear 27 and the second driven gear 33. The first-stage gear train 36 functions as a low-pressure side gear train. The second-stage gear train 37 functions as a high-pressure side gear train. The pump section 11 increases the pressure of DME stepwise by causing the DME to flow through the first-stage gear train 36 and the second-stage gear train 37 successively. On the external surface of the lid 9, a discharge connecting portion 39 is provided. The discharge connecting portion 39 has a discharge port 39a, and is connected with the discharge pipe 4 extending from the injection pump 5 (see FIG. 4). The pump section 11 discharges the DME, the pressure of which has been increased, from the discharge port 39a to the discharge pipe 4 through a first pump section internal passage (not shown).

As shown in FIG. 2, the connection plate 21 has a hole 21a for accommodating the first drive gear 26 and a hole 21b for accommodating the first driven gear 32. The connection plate 21 has an upstream passage 40 and a downstream passage 41. Because having the upstream passage 40 and the downstream passage 41, the connection plate 21 has some space on both sides of the meshed portions of the first drive gear 26 and the first driven gear 32. The upstream passage 40 and the downstream passage 41 serve as passages for DME. The upstream passage 40 communicates with the sub tank 7a through a second pump section internal passage (not shown). Although not illustrated, the connection plate 19 also has holes, an upstream passage, and a downstream passage, which are the same

as the holes 21a and 21b, the upstream passage 40, and the downstream passage 41 in the connection plate 21.

The drive shaft 12 rotates in the direction of a black arrow in FIG. 2, that is, in the clockwise direction. The driven shaft 29 rotates following the rotation of the drive shaft 12 via the gear trains 36 and 37. That is to say, the driven shaft 29 rotates in the direction indicated by the white arrow in FIG. 2, that is, in the counterclockwise direction. When the drive shaft 12 and the driven shaft 29 rotate, the DME having been sent into the pump section 11 flows into the first-stage gear train 36 through the upstream passage 40. The first-stage gear train 36 has a plurality of low-pressure pump chambers 36a and 36b. The DME having reached the first-stage gear train 36 is conveyed toward the downstream passage 41 through the pump chambers 36a or 36b. Each of the pump chambers 36a is defined by the two adjacent teeth 26a of the first drive gear 26 and the inner circumferential surface of the hole 21a. Each of the pump chambers 36b is defined by the two adjacent teeth 32a of the first driven gear 32 and the inner circumferential surface of the hole 21b.

As shown in FIG. 3, the side plate 20 has a hole 20a for inserting the drive shaft 12 and a hole 20b for inserting the driven shaft 29, these two holes 20a and 20b being located adjacently. The diameter of the hole 20a is set larger than the diameter of the drive shaft 12. Therefore, a clearance is provided between the drive shaft 12 and the hole 20a. The diameter of the hole 20b is set larger than the diameter of the driven shaft 29. Therefore, a clearance is provided between the driven shaft 29 and the hole 20b.

The side plate 20 has a communication passage 43 for connecting the downstream passage 41 of the first-stage gear

train 36 to the upstream passage 42 of the second-stage gear train 37. The communication passage 43 includes a first passage 43a, a second passage 43b, and a third passage 43c. The first passage 43a extends in the radial direction of the pump 1. The second passage 43b extends in the axial direction of the pump 1 from the downstream passage 41 of the first-stage gear train 36 and communicates with the first passage 43a. The third passage 43c extends in the axial direction of the pump 1 from the upstream passage 42 of the second-stage gear train 37 and communicates with the first passage 43a. Therefore, the DME, the pressure of which has been increased by the first-stage gear train 36, passes through the second passage 43b, the first passage 43a, and the third passage 43c in that order from the downstream passage 41 and is sent to the upstream passage 42 of the second-stage gear train 37.

The second-stage gear train 37 has a plurality of high-pressure pump chambers 37a and 37b. As shown in FIG. 1A, the DME having reached the second-stage gear train 37 is conveyed to the discharge port 39a through the pump chambers 37a or 37b. Each of the pump chambers 37a is defined by the two adjacent teeth 27a of the second drive gear 27 and the inner circumferential surface of the corresponding hole in the connection plate 19. Each of the pump chambers 37b is defined by the two adjacent teeth 33a of the second driven gear 33 and the inner circumferential surface of the corresponding hole in the connection plate 19. The DME, which has been sent to the discharge port 39a after the pressure thereof has been increased by the second-stage gear train 37, is supplied to the injection pump 5 through the discharge pipe 4. That is, the pump section 11 discharges fluid that has been drawn into a fluid conveying passage, which includes the pump chambers 36a to 37b, from the fluid conveying passage through the pump chambers 36a to 37b. The pressure at the starting point of the fluid conveying passage is the suction pressure of the

pump section 11, and the pressure at the endpoint of the fluid conveying passage is the discharge pressure of the pump section 11.

The lid 9 is fitted with a pipe connecting portion 54. The pipe connecting portion 54 is connected with a leak pipe 55 extending from the tank 2 (see FIG. 4). The pipe connecting portion 54 has a leak port 56 for connecting the internal space of the recess 61 to the leak pipe 55. The motor housing 10a has a communication hole 65 for connecting the internal space of the recess 61 to the motor chamber 60. The side wall of the motor housing 10a is provided with a vent hole 57 for connecting the motor chamber 60 to the upper space of the sub tank 7a.

The sliding portions in the motor section 10 and the sliding portions in the pump section 11, for example, the gears 26, 27, 32 and 33, generate heat by means of sliding operation. Being subjected to the influence of such heat generation, the DME in the sub tank 7a and the DME leaking from the gear trains 36 and 37 into the motor chamber 60 may be vaporized. In this embodiment, the interior of the pump 1 is sealed from the outside. In other words, the pump 1 incorporating the motor 10 is of a shaft enclosed type in which the drive shaft 12 is sealed in the casing 7 and the lid 9. In the shaft enclosed type pump 1, the vaporized DME is possibly accumulated in the sub tank 7a or the motor chamber 60. However, the vaporized DME in the sub tank 7a moves to the motor chamber 60 through the vent hole 57, and the vaporized DME in the motor chamber 60 is returned to the tank 2 through the communication hole 65, the internal space of the recess 61, the leak port 56, and the leak pipe 55 in that order. Therefore, the occurrence of troubles, such as insufficient cooling of the motor section 10 caused by the filling of evaporated DME, is prevented.

In the pump section 11, an internal space 51 is present around a cylindrical surface 12b of the drive shaft 12 at a position adjacent to the drive gears 26 and 27. The internal space 51 includes a first space 51a, a second space 51b, and a third space 51c. The first space 51a is located between the first drive gear 26 and the bearing 14. The first space 51a is a part of the recess 62 provided in the tip-end plate 22. The second space 51b is located between the drive gears 26 and 27. The third space 51c is located on the upper side of the second drive gear 27. In the drive shaft 12, the diameter of a portion ranging from a midway point of the base block 16 to the lower end of the drive shaft 12 is smaller than that of the upper portion. Between this small-diameter portion on the lower end side of the drive shaft 12 and the base block 16, the third space 51c is located.

The first space 51a and the second space 51b are connected to each other by some gap around the key 25 and the groove 12a. Similarly, the second space 51b and the third space 51c are connected to each other by some gap around the key 25 and the groove 12a. As necessary, a communication passage for connecting the first space 51a to the second space 51b may be formed in the first drive gear 26, or a communication passage for connecting the second space 51b to the third space 51c may be formed in the second drive gear 27.

In the recess 62 in the tip-end plate 22, a space 62a is present on the lower end face of the drive shaft 12 beyond the bearing 14. The space 62a is connected to the first space 51a through a gap that the bearing 14 has. The third space 51c is connected to the motor chamber 60 through a gap between the base block 16 and the large-diameter portion of the drive shaft 12, that is, a communication hole 76. As described above, the internal space of the recess 61 of the motor

housing 10a is connected to the motor chamber 60 through the communication hole 65 in the motor housing 10a. Specifically, a space 61a, in which the upper end face of the drive shaft 12 is exposed, is connected to the motor chamber 60 through the communication hole 65.

Therefore, the pressure atmosphere of the space 61a exposed to the upper end face of the drive shaft 12 and the pressure atmosphere of the space 62a exposed to the lower end face of the drive shaft 12 are the same as the pressure atmosphere of the motor chamber 60. The pressure in the motor chamber 60 is approximately equal to the suction pressure of the pump section 11. Therefore, the force based on the pressure in the recess 61, which is applied to the upper end face of the drive shaft 12, and the force based on the pressure in the recess 62, which is applied to the lower end face of the drive shaft 12, are balanced. As a result, opposing thrust loads applied to the drive shaft 12 due to the imbalance of the pressure in the recess 61 and the pressure in the recess 62 cancel each other, so that the thrust load borne by the bearing 13 is alleviated, whereby the durability of the bearing 13 is enhanced.

Also, the pressure atmosphere of the first space 51a is the same as the pressure atmosphere of the second space 51b located adjacently to the first space 51a with the first drive gear 26 being held therebetween. Therefore, the opposing thrust loads applied to the first drive gear 26 due to the imbalance of the pressure in the first space 51a and the pressure in the second space 51b cancel each other. As a result, wear and other types of impairment of the first drive gear 26 are prevented. Similarly, the pressure atmosphere of the second space 51b is the same as the pressure atmosphere of the third space 51c located adjacently to the second space 51b with the second drive gear 27 being held therebetween.

Therefore, opposing thrust loads applied to the second drive gear 27 due to the imbalance of the pressure in the third space 51c and the pressure in the second space 51b cancel each other. As a result, wear and other types of impairment of the second drive gear 27 are prevented.

In the pump section 11, an internal space 52 is present around a cylindrical surface 29a of the driven shaft 29 at a position adjacent to the driven gears 32 and 33. The internal space 52 includes a first space 52a, a second space 52b, and a third space 52c. The first space 52a is located between the first driven gear 32 and the bearing 31. That is, the first space 52a is a part of the recess 64 provided in the tip-end plate 22. The second space 52b is located between the driven gears 32 and 33. The third space 52c is located between the second driven gear 33 and the bearing 30. That is, the third space 52c is a part of the recess 63 provided in the base block 16.

The first space 52a and the second space 52b are connected to each other by some gap between the first driven gear 32 and the cylindrical surface 29a of the driven shaft 29. In the recess 64 in the tip-end plate 22, a space 64a is present on the lower end face of the driven shaft 29. The space 64a is connected to the first space 52a through a gap that the bearing 31 has. In the recess 63 in the base block 16, a space 63a is present on the upper end face of the driven shaft 29. The space 63a is connected to the third space 52c through a gap that the bearing 30 has. The space 63a exposed to the upper end face of the driven shaft 29 in the base block 16 is connected to the space 64a exposed to the lower end face of the driven shaft 29 in the tip-end plate 22 through an in-shaft passage 66 formed in the driven shaft 29. The in-shaft passage 66 extends along the axis of the driven shaft 29.

Therefore, the pressure atmosphere of the space 63a exposed to the upper end face of the driven shaft 29 is the same as the pressure atmosphere of the space 64a exposed to the lower end face of the driven shaft 29. Therefore, the force based on the pressure in the recess 63, which is applied to the upper end face of the driven shaft 29, and the force based on the pressure in the recess 64, which is applied to the lower end face of the driven shaft 29, are balanced. As a result, a thrust load applied to the driven shaft 29 due to the imbalance of the two forces is canceled. Further, the pressure atmosphere of the second space 52b is the same as the pressure atmosphere of the third space 52c located adjacently to the second space 52b with the second driven gear 33 being held therebetween. Therefore, opposing thrust loads applied to the second driven gear 33, which are a thrust load due to the imbalance of pressure in the second space 52b and pressure in the third space 52c and a thrust load due to the imbalance of pressure in the recess 63 and pressure in the recess 64, cancel each other. As a result, wear and other types of impairment of the second driven gear 33 are prevented.

Also, the pressure atmosphere of the first space 52a is the same as the pressure atmosphere of the second space 52b located adjacently to the first space 52a with the first driven gear 32 being held therebetween. Therefore, opposing thrust loads applied to the first driven gear 32 due to the imbalance of the pressure in the first space 52a and the pressure in the second space 52b cancel each other. As a result, wear and other types of impairment of the first driven gear 32 are prevented.

The pressure in the communication passage 43 for connecting the first-stage gear train 36 to the second-stage gear train 37 is equal to the discharge pressure of the first-stage gear train 36, in other words, the suction pressure of

the second-stage gear train 37. Specifically, the pressure in the communication passage 43 is higher than the suction pressure of the first-stage gear train 36, i.e., the suction pressure of the pump section 11, and is lower than the discharge pressure of the second-stage gear train 37, i.e., the discharge pressure of the pump section 11. In other words, it can be said that the pressure atmosphere of the communication passage 43 is the pressure atmosphere of intermediate pressure of the pump section 11. In this embodiment, the communication passage 43 functions as an intermediate-pressure zone.

As shown in FIGS. 1A and 3, the side plate 20 has a pressure introduction passage 67. The pressure introduction passage 67 connects the first passage 43a of the communication passage 43 to the second space 52b of the internal space 52, which is close to the driven shaft 29. The intermediate pressure in the communication passage 43 is introduced to the second space 52b through the pressure introduction passage 67. As described above, the second space 52b is connected to the internal space of the recess 64 in the tip-end plate 22, that is, to the first space 52a and the space 64a. The internal space of the recess 64 is connected to the third space 52c. Therefore, the pressure atmosphere of the internal space 52 around the cylindrical surface 29a of the driven shaft 29, the pressure atmosphere of the space 63a exposed to the upper end face of the driven shaft 29, and the pressure atmosphere of the space 64a exposed to the lower end face of the driven shaft 29 are the same as the pressure atmosphere of the communication passage 43, i.e., the pressure atmosphere of intermediate pressure of the pump section 11.

This embodiment having the above-described configuration has the following advantages.

(1) The pressure atmosphere of the internal space 52, which is close to the driven shaft 29 of the pump section 11, is the pressure atmosphere of intermediate pressure of the pump section 11. Therefore, for example, when compared with the case where the pressure atmosphere of the internal space 52 is the same as the suction pressure or the discharge pressure of the pump section 11, the maximum value of difference in pressure produced between the pump chambers 36b, 37b close to the driven shaft 29 and the internal space 52 is decreased.

Thereupon, for example, when compared with the case where the pressure in the internal space 52 is equal to the suction pressure of the pump section 11, the leakage of DME from the high-pressure pump chambers 37b to the internal space 52 is decreased. Also, for example, when compared with the case where the pressure in the internal space 52 is equal to the discharge pressure of the pump section 11, the leakage of DME from the internal space 52 to the low-pressure pump chambers 36b is decreased. As a result, the efficiency of the pump 1 is improved in total.

Since the leakage of DME between the pump chambers 36b, 37b close to the driven shaft 29 and the internal space 52 is decreased without the use of a sealing member as described above, the size of the pump 1 is made small. Therefore, the pump 1 of this embodiment is suitable as a pump mounted on a vehicle.

(2) According to this embodiment, in the pump section 11, the internal space 52 is connected to the communication passage 43, which functions as an intermediate-pressure zone, via the pressure introduction passage 67. Therefore, the internal space 52 is made to have a pressure atmosphere of intermediate pressure by a simple construction such as the

pressure introduction passage 67.

(3) The communication passage 43 connecting the discharge side of the first-stage gear train 36 to the suction side of the second-stage gear train 37 forms an intermediate-pressure zone. For example, when compared with the intermediate pressure in the case where the low-pressure pump chambers 36a and 36b during the conveyance under pressure in the first-stage gear train 36 function as intermediate-pressure zones, a high pressure, which is the discharge pressure of the first-stage gear train 36, is introduced to the internal space 52. Therefore, the maximum difference in pressure produced between the pump chambers 36b, 37b and the internal space 52 is further decreased. As a result, the efficiency of the pump 1 is further improved.

Also, for example, when compared with the case where an intermediate-pressure zone is set in the pump chambers 36a, 36b, 37a, 37b during the stroke of conveyance under pressure, the layout of the pressure introduction passage 67 is simple, which is advantageous in decreasing the size of the pump 1.

As shown in FIG. 5, in a second embodiment, a shaft seal device 71 is provided between the base block 16 and the drive shaft 12. The shaft seal device 71 disconnects the motor chamber 60 from the third space 51c of the internal space 51 in the pump section 11. The shaft seal device 71 includes, for example, a lip type seal. The side plate 20 has a pressure introduction passage 72. The pressure introduction passage 72 connects the first passage 43a of the communication passage 43 to the second space 51b of the internal space 51.

Therefore, the intermediate pressure of the communication passage 43 is introduced to the second space 51b of the internal space 51 through the pressure introduction passage

72. That is to say, the pressure atmosphere of the internal space 51 around the cylindrical surface 12b of the drive shaft 12 and the pressure atmosphere of the space 62a exposed to the lower end face of the drive shaft 12 are the same as the pressure atmosphere of intermediate pressure of the pump section 11.

In this embodiment, therefore, the maximum difference in pressure produced between the pump chambers 36a, 37a close to the drive shaft 12, and the internal space 51 is also decreased. As a result, in the relationship between the pump chambers 36a, 37a and the internal space 51 close to the drive shaft 12 as well, as in the case of the above-described first embodiment, that is, as in the relationship between the pump chambers 36b, 37b and the internal space 52 close to the driven shaft 29, an effect of decreasing DME leakage is achieved. Since the leakage of DME is decreased in both of the relationship between the pump chambers 36a, 37a and the internal space 51 close to the drive shaft 12 and the relationship between the pump chambers 36b, 37b and the internal space 52 close to the driven shaft 29, the efficiency of the pump 1 is further improved.

As shown in FIG. 6, in a third embodiment, the vent hole 57 in the motor housing 10a and the pressure introduction passage 67 in the side plate 20 are eliminated from the above-described first embodiment. The space 63a (see FIG. 1A) exposed to the upper end face of the driven shaft 29 in the recess 63 is connected to the motor chamber 60 through a communication hole 75 penetrating the base block 16. The third space 51c (see FIG. 1A) of the internal space 51 close to the drive shaft 12 is connected to the motor chamber 60 through the gap between the base block 16 and the large-diameter portion of the drive shaft 12, that is, the communication hole 76. Therefore, the pressure atmosphere of

the internal spaces 51 and 52 is the same as the pressure atmosphere of the motor chamber 60.

At a midway point of the leak port 56 in the pipe connecting portion 54, a pressure regulating valve 77 is disposed. The pressure regulating valve 77 is a differential pressure regulating valve including a valve element 77a and an urging spring 77b. The pressure regulating valve 77 opens and closes the leak port 56 according to a difference between the pressure on the motor chamber 60 side applied to the valve element 77a and the pressure on the tank 2 (see FIG. 4) side similarly applied to the valve element 77a.

The high-pressure pump chambers 37a and 37b (see FIG. 1A) function as a high-pressure zone. The pressure in the high-pressure zone is higher than the pressure in the internal spaces 51 and 52. The pressure in the internal spaces 51 and 52 and the motor chamber 60 is increased due to the leakage of DME from the pump chambers 37a and 37b, that is, the pressure leakage, and the vaporization of DME in the motor chamber 60. If the pressure in the internal spaces 51 and 52 and the motor chamber 60 becomes higher than a predetermined value, the valve element 77a of the pressure regulating valve 77 moves in the valve opening direction against the urging force in the valve closing direction generated by the urging spring 77b and a force in the valve closing direction generated by the pressure in the section connected to the tank 2. Thus, the valve element 77a releases the leak port 56. Therefore, the pressure in the internal spaces 51 and 52 and the motor chamber 60 tends to be decreased by the sending-out of pressure to the tank 2 through the leak port 56, so that the pressure returns to the aforementioned predetermined value.

In a state in which the leak port 56 is open, if the pressure in the internal spaces 51 and 52 and the motor

chamber 60 becomes lower than the predetermined value, the valve element 77a of the pressure regulating valve 77 is moved in the valve closing direction by the urging force in the valve closing direction of the urging spring 77b and a force in the valve closing direction generated by the pressure of the section connected to the tank 2, so that the leak port 56 is closed. Therefore, the pressure in the internal spaces 51 and 52 and the motor chamber 60 tends to be increased by the leakage and vaporization of DME, so that the pressure returns to the aforementioned predetermined value.

That is to say, the pressure regulating valve 77 opens and closes the leak port 56 autonomously so as to keep the pressure in the internal spaces 51 and 52 and the motor chamber 60 at the predetermined value. The construction of the pressure regulating valve 77 of an autonomous type is simpler than that of a pressure regulating valve of, for example, an external control type. The aforementioned predetermined value, that is, the target of regulation of the pressure in the internal spaces 51 and 52 and the motor chamber 60 accomplished by the pressure regulating valve 77 is set to the intermediate pressure of the pump section 11 in the steady-state operating condition, for example, to the discharge pressure of the first-stage gear train 36. The setting of the pressure regulation target is concretely performed by the adjustment of the spring force of the urging spring 77b. Therefore, as in the case of the above-described second embodiment, the internal spaces 51 and 52 have the pressure atmosphere of intermediate pressure of the pump section 11. Therefore, the leakage of DME between the pump chambers 36a, 36b, 37a, 37b and the corresponding internal space 51, 52 is decreased.

In this embodiment, the target value of the pressure in the internal spaces 51 and 52 is changed easily by changing

the operating characteristics of the pressure regulating valve 77, for example, the spring force of the urging spring 77b. Therefore, the pressure in the internal spaces 51 and 52, which varies from pump to pump, is corrected to a desired value by simple work. For example, in the above-described second embodiment, in order to correct the pressure in the internal spaces 51 and 52, which varies from pump to pump, it is necessary to change the diameters etc. of the pressure introduction passages 67 and 72. Such work for changing the diameter and other measurements is troublesome. In this embodiment, the correction of pressure is made easily.

The pressure leakage from the pump section 11 is an inevitable phenomenon. The pressure leakage tends to increase the pressure in the internal spaces 51 and 52. In this embodiment, the internal spaces 51 and 52 are caused to have an intermediate pressure atmosphere by utilizing the tendency for the pressure in the internal spaces 51 and 52 to increase due to this inevitable pressure leakage from the pump section 11. Unlike the pump 1 of the second embodiment, in the pump 1 of this embodiment, the internal spaces 51 and 52 need not be isolated from the motor chamber 60. In the pump 1 of this embodiment, in which the internal spaces 51 and 52 and the motor chamber 60 communicate with each other, the DME leaking from, for example, from the second-stage gear train 37 is positively supplied to the motor chamber 60 through the internal spaces 51 and 52 and the communication holes 75 and 76. As a result, the motor section 10 is cooled properly by the liquid DME supplied to the motor chamber 60. Thereby, the operation of the motor section 10 is stabilized.

In this embodiment, the communication holes 75 and 76, the motor chamber 60, the communication hole 65, the internal space of the recess 61, the leak port 56, and the leak pipe 55 (see FIG. 4) function as a pressure regulation passage that

connects the tank 2 functioning as a low-pressure zone to the internal spaces 51 and 52.

As shown in FIG. 7, in the pump 1 in accordance with a fourth embodiment, the pump 1 of the above-described third embodiment is changed. Specifically, the upstream-side of the leak port 56 of the pipe connecting portion 54 is connected to the upper space of the sub tank 7a. The lid 9 has an internal passage 79 for connecting the internal space of the recess 61 to the upper space of the sub tank 7a. The vaporized DME in the motor chamber 60 is discharged through the communication hole 65, the internal space of the recess 61, and the internal passage 79, and is returned to the tank 2 through the leak port 56 and the leak pipe 55 together with the DME vaporized in the sub tank 7a.

In the internal passage 79, the pressure regulating valve 77 is disposed to regulate the pressure in the motor chamber 60 so as to be an intermediate pressure by the same operation as that in the above-described third embodiment. In this embodiment, the sub tank 7a functions as a low-pressure zone. The communication holes 75 and 76, the motor chamber 60, the communication hole 65, the internal space of the recess 61, and the internal passage 79 function as a pressure regulation passage that connects the internal spaces 51 and 52 to the low-pressure zone, i.e., the sub tank 7a.

As shown in FIG. 8, in a fifth embodiment, the above-described third embodiment is changed. Specifically, the motor section 10 is arranged at the lower part (right-hand side as viewed in FIG. 8) of the casing 7, and the pump section 11 is arranged at the upper part (left-hand side as viewed in FIG. 8) of the casing 7. That is to say, the pump 1 is mounted on a vehicle in a state in which the pump section 11 is at the upper position and the motor section 10 is at the

lower position.

By this configuration, the pump section 11 and the discharge connecting portion 39 installed to the lid 9 are arranged so as to be close to each other. Therefore, the first pump section internal passage (not shown) for connecting the pump section 11 to the discharge connecting portion 39 is laid out easily, which is advantageous in decreasing the size of the pump 1. Also, since the motor section 10 is arranged at the lower part of the casing 7, the liquid level of DME in the motor chamber 60 is surely located at the upper part of the motor chamber 60. Therefore, the stators 10b and the rotor 10c are less liable to be exposed above the liquid level of DME, so that they are cooled properly by DME (liquid).

In this embodiment, the upstream-side of the leak port 56 is connected to the internal space of the recess 62 in the tip-end plate 22. The leak port 56 and the motor chamber 60 are connected to each other through the internal space 51 close to the drive shaft 12 and the communication hole 76. Therefore, the vaporized DME in the motor chamber 60 is discharged into the tank 2 through the communication hole 76, the internal space 51, the leak port 56, and the leak pipe 55 (see FIG. 4).

The pressure in the internal space 51 tends to be increased under the influence of DME leakage from the high-pressure pump chambers 37a and 37b (see FIG. 1A), which function as high-pressure zones, and under the influence of vaporization of DME in the motor chamber 60. On the other hand, the pressure in the internal space 51 is released into the tank 2 through the leak port 56 and the leak pipe 55. The pressure regulating valve 77 regulates the pressure in the internal space 51 so as to be the intermediate pressure of the pump section 11 by regulating the opening of the leak port 56

and the degree of sending-out of pressure from the internal space 51.

In this embodiment, the communication hole 75 is eliminated. That is to say, the internal space 52 close to the driven shaft 29 is isolated from the motor chamber 60. However, the internal space 52 is connected to the communication passage 43 between the gear trains 36 and 37 through the pressure introduction passage 67. That is to say, the internal space 52 close to the driven shaft 29 is made to have a pressure atmosphere of intermediate pressure of the pump section 11 by the same method as that in the above-described first embodiment.

In this embodiment, the pressure in the internal space 51 close to the drive shaft 12 is regulated directly by the pressure regulating valve 77. Contrarily, for example, in the above-described third embodiment, the pressure in the motor chamber 60 is regulated directly, and resultantly the pressure in the motor chamber 60 is reflected to the pressure in the internal space 51. In this embodiment, therefore, when compared with the above-described third embodiment, the operation of the pressure regulating valve 77 is immediately reflected to the pressure in the internal space 51. Therefore, the pressure in the internal space 51 is further stabilized. As a result, the leakage of DME between the low-pressure pump chambers 36a, the high-pressure pump chamber 37a and the internal space 51 close to the drive shaft 12 is restrained more effectively.

In this embodiment, the internal space of the recess 62, the leak port 56, and the leak pipe 55 (see FIG. 4) function as a pressure regulation passage that connects the internal space 51 to the tank 2.

The invention may be embodied in the following forms.

By changing the above-described first or second embodiment, in the first-stage gear train 36 or the second-stage gear train 37, the pump chambers 36a, 36b, 37a, 37b during the conveyance under pressure are grasped as intermediate-pressure zones. Specifically, in the case of the modification of the first embodiment, the internal space 51 is connected to the intermediate-pressure zone through the pressure introduction passage. In the case of the modification of the second embodiment, the internal spaces 51 and 52 are connected to the intermediate-pressure zone through the pressure introduction passage.

In the above-described second embodiment, the pressure introduction passage 67 is eliminated. That is to say, only the internal space 51 is made to have the intermediate pressure.

In the above-described third to fifth embodiments, the pressure regulating valve 77 is of an autonomous type (differential pressure regulating valve). By changing this, a valve of an external control type, such as a solenoid valve, is used as a pressure control valve. In this case, the modification of the third to fifth embodiments is provided with a pressure sensor and control means (described below). The pressure sensor detects the pressure in the corresponding internal spaces 51 and 52 or the pressure in a space having the same pressure atmosphere as that of the said space. The control means, which is, for example, a computer, controls the opening and closing of the pressure control valve based on detected information sent from the pressure sensor. Thus, the pressure regulation passage that connects the internal spaces 51 and 52 to the low-pressure zone can be opened or closed according to the pressure in the corresponding internal spaces

51 and 52 without being affected by the pressure state on the low-pressure zone side. Therefore, the pressure in the corresponding internal spaces 51 and 52 can surely be regulated so as to have a predetermined value.

In the above-described embodiments, the invention is embodied in the pump 1 of a type such as to be mounted outside the tank 2. By changing this, the invention is embodied in a gear pump of what is called an in-tank type, which is contained in the tank 2. In this case, the casing 7 is eliminated.

The fluid handled by the gear pump is not limited to DME. The invention may be embodied in a gear pump that handles a liquid (gas) other than DME.

In the above-described embodiments, the invention is embodied in the two-stage gear pump. However, the invention is not limited to the gear pump of this type. The invention may be embodied in the gear pump of a plurality of stages other than two stages, such as three stages or four stages. Alternatively, the invention may be embodied in a one-stage gear pump.

In the above-described embodiments, the gear pump is of a shaft enclosed type, i.e., a type such that the motor is incorporated. However, the gear pump may be of a shaft open type, i.e., a type such that the pump section is driven by an external motor.

The gear pump in accordance with the present invention is not limited to a vehicular gear pump that sends a liquefied gas fuel under pressure to an internal combustion engine. The present invention may be applied to a gear pump used to send hydraulic fluid etc. under pressure, for example, in a machine

tool.

The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.